Range expansion of short-winged grasshopper *Pezotettix giornae* (Orthoptera, Acrididae) along the northern edge of its range in Central Europe

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Abstract

Orthoptera species distribution ranges are dynamically shifting because of climate change. This article documents the expansion of the short-winged grasshopper *Pezotettix giornae* in Western and Central Europe between 1990 and 2024. Published records from Central Europe (Austria, Slovakia, Hungary, and the Czech Republic) are supplemented with data from public databases and targeted field surveys, particularly in southeastern Moravia and the Burda Hills region of southern Slovakia. Whereas *P. giornae* was previously abundant mainly in the Mediterranean reaching northwards into central Hungary, its range has gradually shifted northward over the past 30 years, now reaching central France, Austria, Slovakia, and the Czech Republic, with single individuals transported to northern France, northern Switzerland, central Germany, and the Netherlands. The increase in abundance and the number of newly recorded localities indicate the dynamic spread of this species despite its inability to fly. This expansion is facilitated by climate warming, the species' ability to colonize ruderal and successional habitats, and passive dispersal via transportation, particularly along road and railway corridors. The case of *P. giornae* demonstrates that even brachypterous species with limited dispersal ability can undergo significant range shifts. This trend has important implications for ecological modeling and the prediction of future species distributions and biodiversity conservation strategies in the changing European landscape.

Keywords

Brachyptery, Central Europe, climate change, passive transport, range expansion, ruderal habitats

Introduction

Climate exerts a strong direct influence on insect development, reproduction, and survival (Huntley 1991) while also acting indirectly through alterations in vegetation, landscape structure, and land use (e.g., Masters et al. 1998, Neff et al. 2022). Many studies have documented poleward shifts in species range margins in higher-latitude regions alongside contractions or local extinctions at lower-latitude or lowland margins (Menéndez et al. 2014, Beckmann et al. 2015, Mason et al. 2015). These changes are particularly significant for endemic or relict populations of montane Orthoptera with limited mobility, as rising temperatures could lead to a significant reduction in suitable habitats. While highly mobile species can move to higher elevations or higher latitudes, those with limited dispersal capacity, such as ecological specialists, remain vulnerable (e.g., Kočárek et al. 2013, Löffler et al. 2019, Fartmann et al. 2021).

Many Orthoptera species, including long-winged taxa such as *Aiolopus thalassinus* (Fabricius, 1781), *Calliptamus italicus* (Linnaeus, 1758), *Conocephalus fuscus* (Fabricius, 1793), *Phaneroptera falcata* (Poda, 1761), *P. nana* Fieber, 1853, *Oecanthus pellucens* (Scopoli, 1763), *Mecostethus parapleurus* (Hagenbach, 1822), and *Ruspolia nitidula* (Scopoli, 1786) are currently expanding northward in Europe (Kleukers et al. 1996, Fedor and Majzlan 2001, Kočárek et al. 2008, Holuša et al. 2013, Mückstein and Vlk 2015, Kenyeres et al. 2019, Budrys et al. 2019, Elmqvist 2020, Kaláb et al. 2021, Verhees

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2024). Range expansions have also been observed in species with limited mobility, such as *Euchorthippus declivus* (Brisout de Barneville, 1849) and *Meconema meridionale* A. Costa, 1860 (Holuša et al. 2007, Vlk et al. 2012). While the former likely spreads naturally and more slowly, the rapid expansion of *M. meridionale* has been facilitated by automobile transport (Grobelny et al. 2019, Köhler et al. 2022). The northward range shift of Orthoptera species has been documented in both Europe and North America (McAlpine and Ogden 2012).

Changes in species distribution are usually identified by observing newly established populations, as individual dispersal often occurs below detectable thresholds, particularly among insects and other terrestrial invertebrates (Didham et al. 2020, Wilson and Fox 2021). Distinguishing true dispersal and abundance increases from sampling artifacts requires broad-scale and long-term sampling across the entire range (e.g., Braun et al. 1995, Berg and Zuna-Kratky 1997, Krištín et al. 2007).

In countries covering the central, northern, and western Pannonian regions—Hungary (e.g., Nagy et al. 2010), Slovakia (orthoptera.sk), Austria (Zuna-Kratky et al. 2017, orthoptera.at), and the Czech Republic (Marhoul et al. 2019)—intensive monitoring of Orthoptera has been conducted using defined methodologies for approximately 20 years. This has yielded detailed data per faunistic grid cell, enabling changes in distribution to be detected.

Pezotettix giornae (Rossi, 1794) is a xerothermophilic, flightless species that is primarily distributed across the Mediterranean region, spanning southern Europe, North Africa, and the Middle East (Harz 1975, Hochkirch et al. 2016). Over the past 20 years, its range has expanded northward (Lederer 2004, Ranner and Riegler 2004, Koschuh and Zechner 2006, Wöss et al. 2011, Wöss 2017, Krištín et al. 2020, Hochkirch et al. 2020, 2023). Its arrival in the Czech Republic was anticipated, resulting in repeated surveys of potential sites in the southeastern part of the country near the Slovakian border.

Monitoring *P. giornae* is relatively straightforward because, despite its small size, this grasshopper is highly active, easily observable, and can be readily caught. Adult activity is concentrated between August and October, with the last individuals surviving until November (Fontana et al. 2002, Massa et al. 2012, Wöss 2017). Generally, members of the Acrididae family tend to be easier to detect late in the season when individuals are older and less able to escape from observers (Browde et al. 1992).

This study documents the increase in abundance and spread of *P. giornae* in Western and Central Europe. It also describes its distribution in the Pannonian region in more detail by providing detailed observations from monitored localities in southern Slovakia and the southeastern part of the Czech Republic.

Materials and methods

Mapping the distribution in Europe.—To demonstrate changes in the distribution of *P. giornae* in Europe, data were collected up to the end of 2024 from multiple sources. The data include records extracted from the Global Biodiversity Information Facility (GBIF) (GBIF.org 2025), which also includes data from Observation.org and all available quality-grade research from iNaturalist; however, we excluded the iNaturalist data from GBIF and used exported data from iNaturalist directly (iNaturalist community 2025). These data are complemented by all available data from Austria provided by the mapping team of the ARGE Heuschrecken Österreichs led by Thomas Zuna-Kratky, from Hungarian literature (Nagy et al. 2010), from Croatian and Serbian literature (Szövényi and Puskás 2012, Skejo and Stankovic 2014, Šerić Jelaska and Skejo 2014, Gomboc and Šegula 2014, Skejo et al. 2023), from Slovakia published on the Orthoptera.sk website (Krištín 2025), and from the sampling published in the current study. Only records with coordinates and year information were retained, while duplicates, defined by identical location and time, were removed from the dataset. We used OpenStreetMap© data (https://www.openstreetmap.org/copyright) for all maps. For those requiring a topographic background, the OpenTopoMap© style (https://opentopomap.org) was used.

Local studies.—**The Burda Hills (southern Slovakia).** The Burda Hills and surrounding areas were studied in 1992–1994, 1996–1998, and again after a 20-year interval in 2013–2014. The surveys included sweep-netting and visual observation of grassy, herbaceous, and shrubby vegetation in steppe habitats and forest edges. Sweep-netting was not quantified, consisting of continuous sampling over one to two hours per study site. On 26 October 2013 and 26 October 2014, population density was estimated within ten plots, each measuring 1 m^2.

Southeastern Moravia (Czech Republic). In the last ten years, potential localities in the southeastern part of the Czech Republic have been repeatedly surveyed for *P. giornae*. The surveys have focused particularly on railway stations and the surroundings of two intersecting main railway lines, with the most recent visit on 23 October 2023. During the 2024 season, the survey was extended beyond the railway corridor to include areas near major roadways, especially highway rest areas used for international truck transport. Between 3 September and 9 November 2024, targeted inspections were conducted at five rest areas and six highway exits along the E65 (D2) highway, at eight rest areas and gas stations along the E461 (D52) road, at two gas stations on road 415, and at two more along the E55 road. Abundances were estimated within ten plots, each measuring 1 m^2.

Results

Mapping the distribution in Europe.—We used 13,121 records from GBIF (GBIF.org 2025), 6,021 records from iNaturalist (iNaturalist community 2025), 209 records from mapping in Austria, 135 records from Hungary (Nagy et al. 2010), 42 records from Croatia and Serbia (Szövényi and Puskás 2012, Skejo and Stankovic 2014, Šerić Jelaska and Skejo 2014, Gomboc and Šegula 2014, Skejo et al. 2023), 31 records from Slovakia (Krištín 2025) and 60 from our survey. *P. giornae* is currently recorded across large parts of southern Europe, including the Iberian Peninsula, Italy, the Balkans, and the Pannonian Basin, forming a largely continuous core distribution. Toward the north and northwest, this continuous range gradually breaks into scattered and isolated occurrences (Fig. 1).

In France, although *P. giornae* has been recorded around Paris since before 2009, the number of observations has increased steadily over time, and a new locality has recently been discovered north of Paris. The species was not recorded in Germany until 2018. The first confirmed occurrence was documented in 2019 in North Rhine-Westphalia, followed by the discovery of two additional nearby localities from 2020 onwards. By 2023, *P. giornae* had also been recorded in Baden-Württemberg near the Swiss border. In the same year as the first German record (2019), a single individual was also discovered in the Netherlands, representing a highly isolated occurrence beyond the continuous distribution range (Fig. 1).

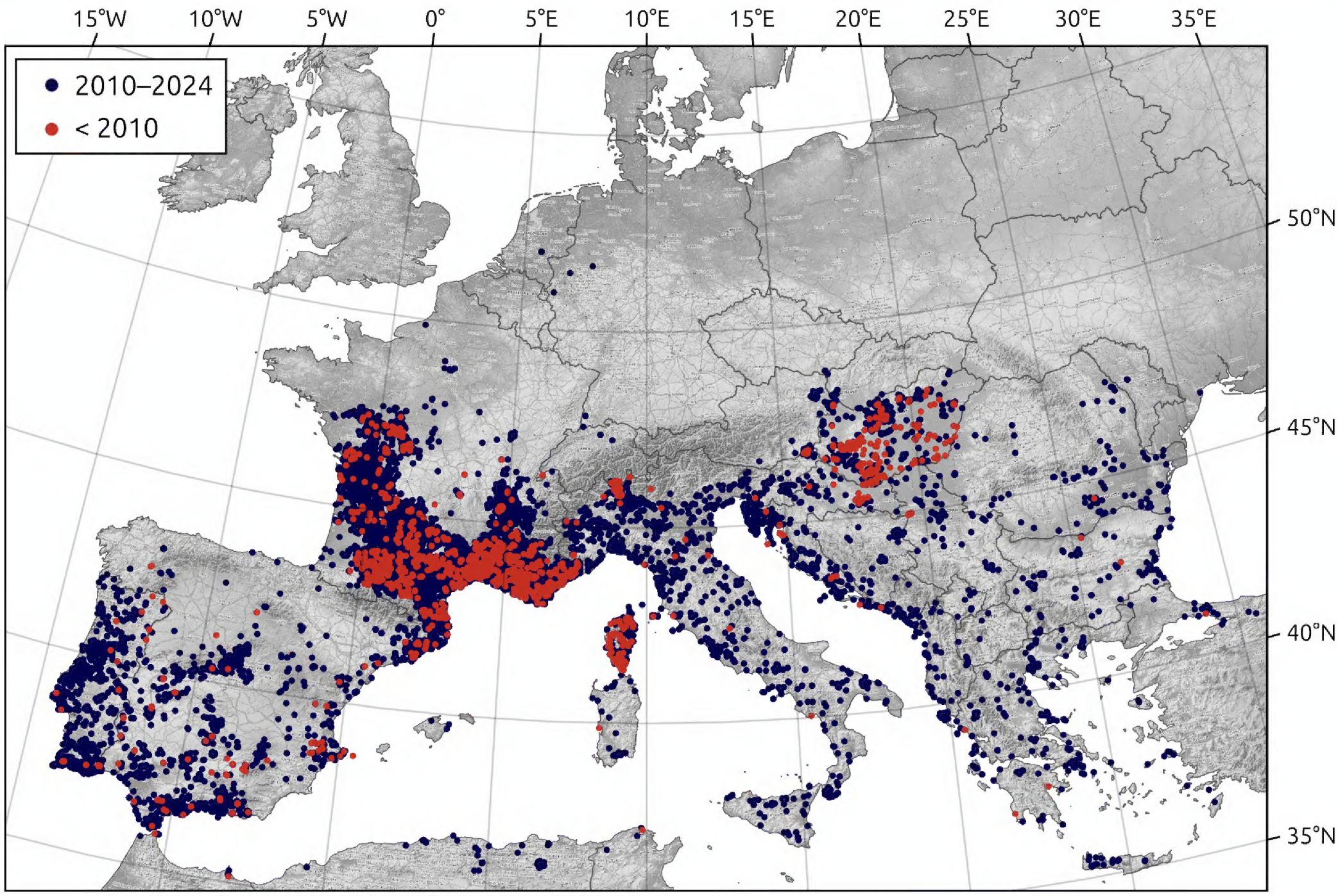

Fig. 1. Known distribution of *Pezotettix giornae* in Europe, depicted in two time periods: before 2010 (red) and from 2010 (blue).

Pezotettix giornae primarily occurs in lowland areas of the Pannonian Basin in Central Europe as well as in the surrounding lower elevations of the southern slopes of the Carpathians and in mountain ranges rising from the Pannonian plain. The northernmost records are from the southeastern part of the Czech Republic (Fig. 1).

Figure 2 illustrates the progressive spread of *P. giornae* in Central Europe, with emphasis on the northern boundary of its distribution across different time periods. Until 2009, *P. giornae* was found in Hungary, southern Slovakia, southeastern Austria, Slovenia, Croatia, and Romania. The first records in the northeastern parts of Austria occurred in 2004, and a further spreading has been observed since 2011, especially in the surroundings of Vienna. In Austria, *P. giornae* also occurs in the southern regions of Burgenland, southern Styria, and southern Carinthia. A large cluster of records has been found around Vienna and in the northern part of Burgenland, from where the occurrence continues into the Malé Karpaty Mts., with another significant concentration around the Slovak capital Bratislava (Fig. 2).

In Slovakia, prior to 2009, the species was mostly confined to the southernmost areas where the Danube flows south into Hungary. Since 2016, however, new localities have been reported in southern Slovakia, including sites near the town of Komárno at the Hungarian border and locations in western Slovakia near the capital, Bratislava. Recently, localities are mainly known from the southern regions, with the highest concentration in the Burda Hills (Fig. 2).

In Hungary, the species is present throughout the country, although the distribution is clustered, with most localities concentrated in the hilly regions of central and northern Hungary. The distribution has remained stable throughout the entire period, primarily in lowland areas. From 2020 to 2025, populations became denser toward the borders with Austria and Slovakia. Although there are no records from Duna-Ipoly National Park in Hungary, there is a locality just beyond its northern border near the Slovakian town of Šahy (Fig. 2).

Local studies.—In the Burda Hills in southern Slovakia in the 1990s, *P. giornae* was known only from two localities on its southern foothills. It was not found at other nearby sites, including the adjacent hills with the PR Vršok (Hegyfárok) nature reserve. The abundance at both known sites was minimal, with only one female found at each site. However, 20 years later, in the 2010s, *P. giornae* was found at 8 out of 11 surveyed sites throughout the entire southern slopes of the Burda Hills, from east to west. It was also found on Hegyfárok (Fig. 3). Densities exceeded 10 individuals per 10 m^2 in nearly all locations (Suppl. material 1). The species was mostly found in forest clearings covered with tall, dry vegetation, but it was also found in leaf litter.

In southeastern Moravia, *P. giornae* was recorded in 3 out of 18 studied localities in the autumn of 2024, whereas it was not detected in 2023. A dense population of dozens of individuals per square meter was found along the D2 highway at the rest area at the former Lanžhot border crossing, approximately 5 km from

the Czech-Slovak border, coming from Bratislava. On the opposite side of the highway, the population density was lower, with approximately one individual observed in 1 m² squares along a shrub line. Another occurrence was confirmed at the cloverleaf junction at Exit 48 near the town of Břeclav, about 10 km from the Czech-Slovak border, again on the side coming from Bratislava. Only one pair was found here, with no individuals detected on the opposite side of the highway. At the Ladná rest area, which has a

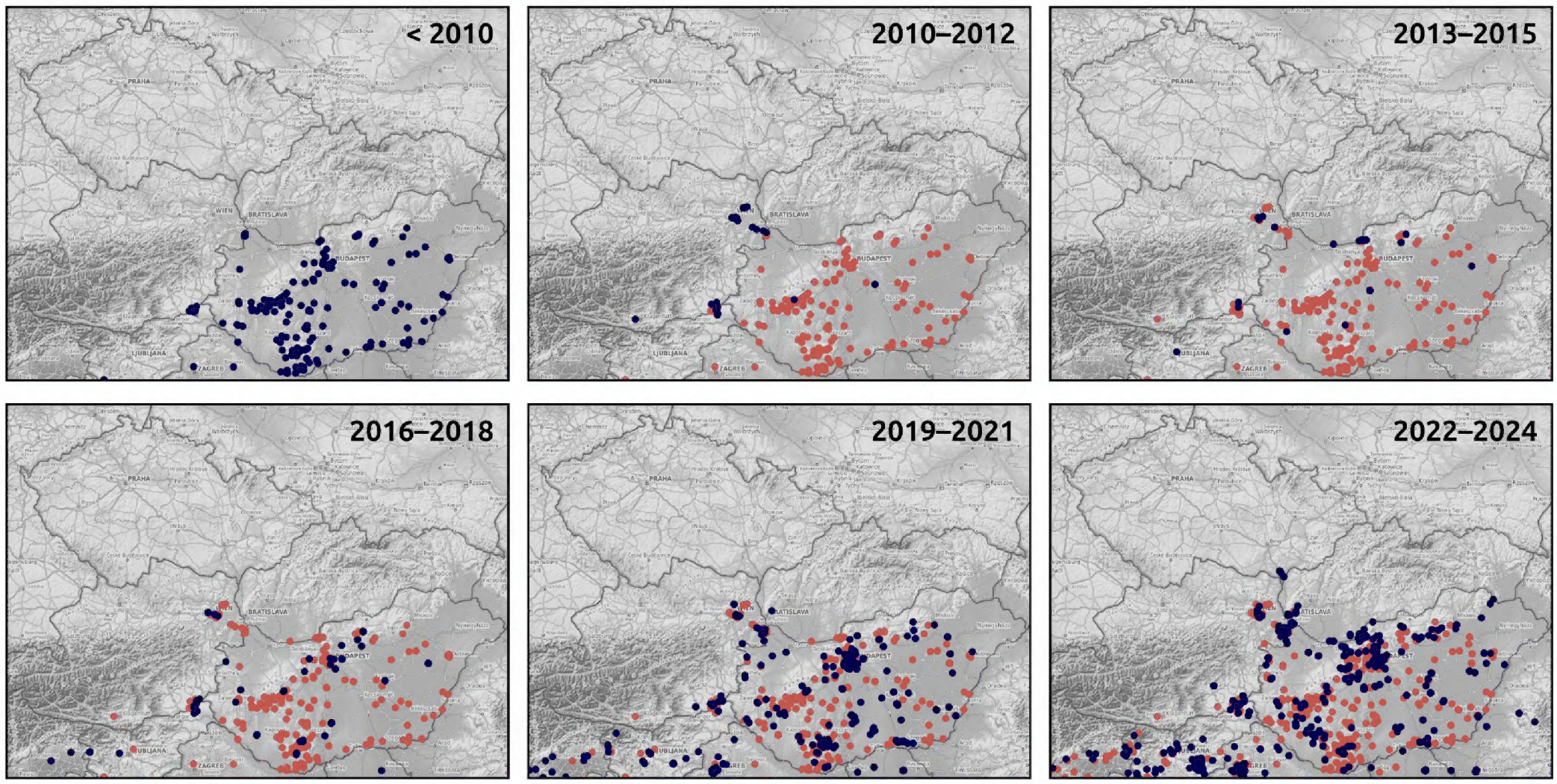

Fig. 2. Spatiotemporal occurrence of *Pezotettix giornae* in Hungary, Austria, the Czech Republic, and Slovakia. Panels show records up to 2009 and then successive three-year intervals up to 2024. Blue points represent the records in specific time periods, illustrating the species' gradual northward expansion, while red points represent all occurrences recorded prior to that period.

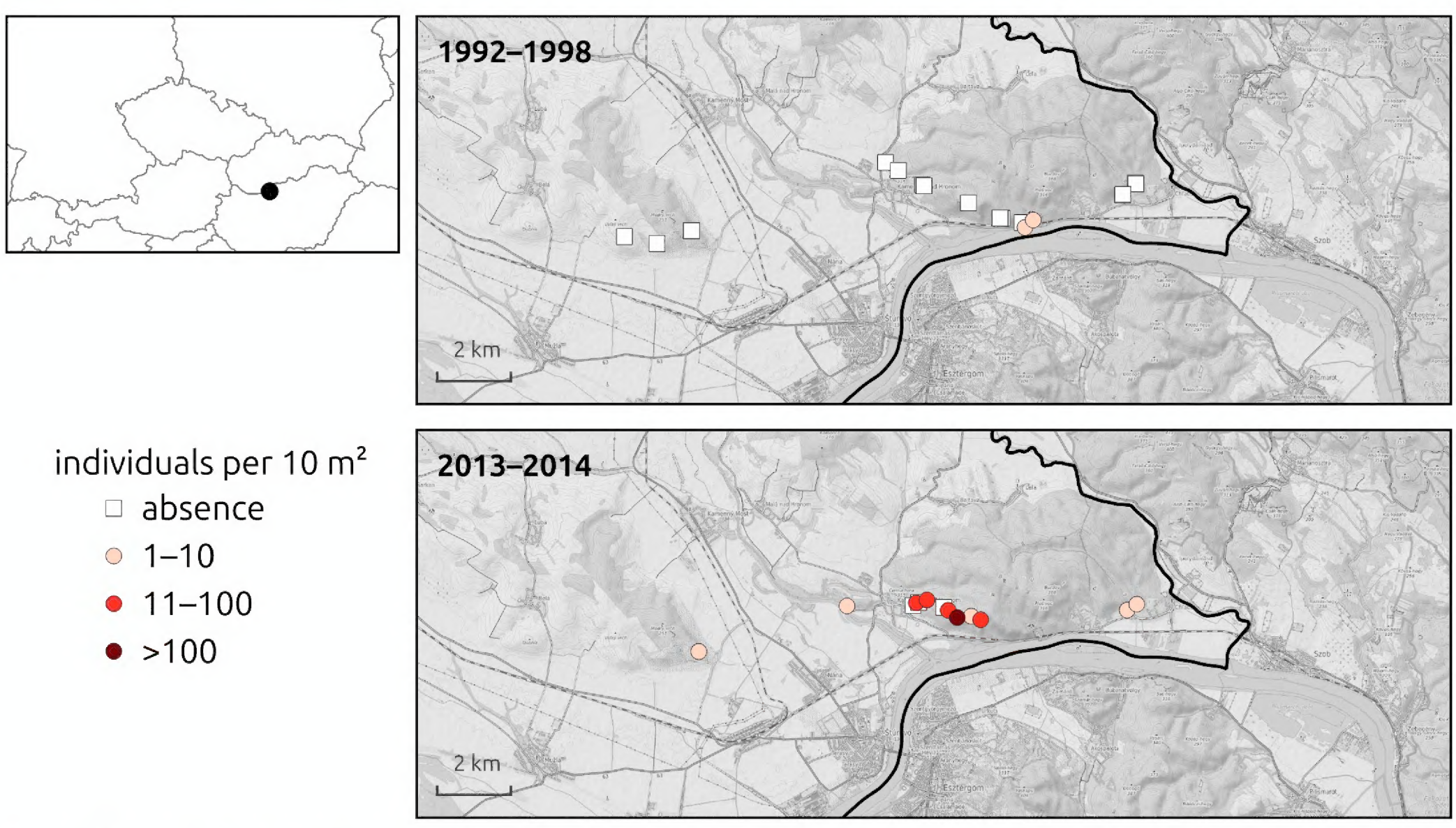

Fig. 3. Changes in the distribution and abundance of *Pezotettix giornae* in the Burda Hills (southern Slovakia) between the 1990s and 2010s. Colors indicate the total number of specimens recorded per study site in the 1990s and density per 10 m² in the 2010s.

petrol station and is located approximately 15 km from the border, the species was abundant again on the side facing Bratislava. Two females were observed on the opposite side (Fig. 4). *P. giornae* was particularly prevalent in shrub stands and in taller vegetation along linear shrub formations (Fig. 5).

Discussion

Range shifts and population trends in Central Europe.—The current northern boundary of *P. giornae* distribution in Western and Central Europe runs through central France and continues along the southern slopes of the Alps, reaching up to 1,110 meters above sea level in southern Switzerland (Thorens and Nadig 1997). It then passes through northern Italy (Köhler 2024) and Carinthia, extending to the eastern part of Lower Austria (Wöss et al. 2011) and southern Moravia in the Czech Republic. The boundary then passes slightly further south through southern Slovakia, eastern Hungary, and northern Romania. Occurrence of single individuals is known around Paris (iNaturalist community 2025), from northern Switzerland (GBIF.org 2025), the adjacent area of Baden-Württemberg (Hochkirch et al. 2023) and in North Rhine-Westphalia in central Germany (Hochkirch et al. 2020).

Czech Republic. The occurrence of *P. giornae* in the Czech Republic represents a well-documented and ecologically meaningful range extension rather than a consequence of insufficient sampling. Southeastern Moravia, where the species was first recorded in 2024, is among the most intensively studied regions for Orthoptera in the country. This area has been subjected to systematic faunistic mapping for several decades, including repeated regional surveys, targeted monitoring, and inventories within both protected areas and anthropogenically influenced habitats (e.g., railway corridors and road verges) (Holuša et al. 2013, Marhoul et al. 2019). Southeastern Moravia is widely recognized as a major biogeographical gateway for thermophilous species expanding northwards from the Pannonian Basin, a pattern repeatedly documented in Orthoptera (Kočárek et al. 2008, Holuša et al. 2007, Holuša et al. 2013, Kaláb et al. 2021). Numerous southern and Pannonian species have reached their northern range limits or established new populations in this region during recent decades, reflecting its transitional position between the Pannonian lowlands and Central European landscapes.

Austria. Redtenbacher (1900) mentioned the species for the first time from Austria, but this was not confirmed until the 1990s (Adlbauer and Sackl 1993). Another record followed in 1999, south of Kalk (Kalch) in southern Burgenland (Lederer 2004), and there have been further observations near Radochen in the Radkersburg district of Styria (Koschuh and Zechner 2006). In northern Burgenland, the species has been known only since 2004 (Ranner and Riegler 2004), for Carinthia since 2010, and for Lower Austria and Vienna since 2011 (Wöss et al. 2011). These were new colonizations, as these sites have been surveyed quite intensively since the 1990s (Wöss 2017).

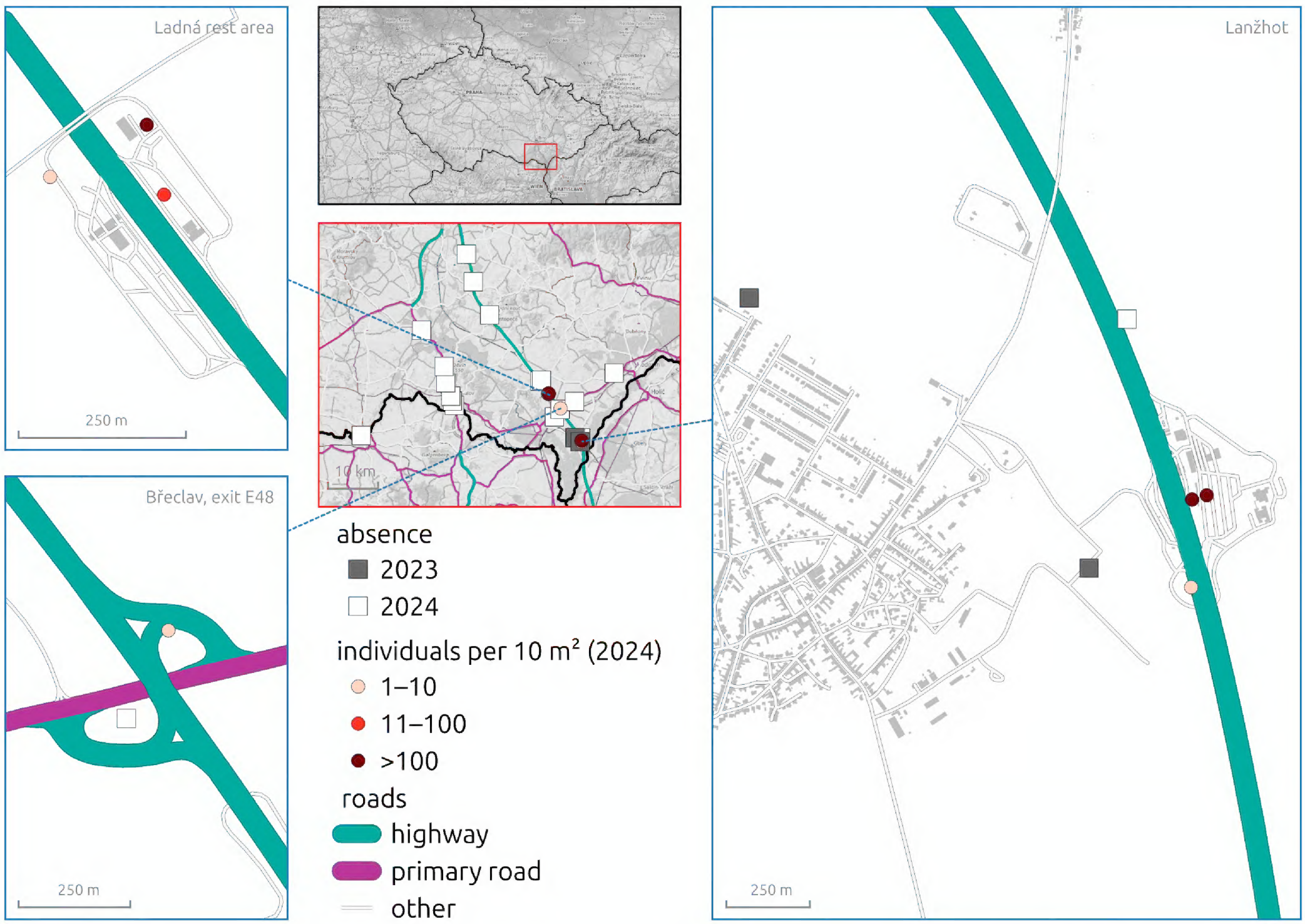

Fig. 4. Detailed occurrence and abundance of *Pezotettix giornae* in southeastern Moravia (Czech Republic) in 2023 and 2024, with details of three study sites where *P. giornae* was recorded. Colors indicate density per 10 m².

Fig. 5. Mating pair of *Pezotettix giornae* (**A**); shrub vegetation at the former Lanžhot border crossing, Czech Republic, where the grasshoppers were found in the shrubs on the left (**B**); and a strip of shrubs near the Břeclav highway exit, where a pair of *P. giornae* was recorded at the edge (**C**).

Slovakia. Despite the species' wide distribution and abundant populations in the neighboring area of northern Hungary near the Slovak border, where it has been known since the early 20th century (Nagy et al. 2010), the earliest record from southern Slovakia dates only from the late 20th century (Kočárek 1999), representing the first documented introduction. The species was unknown in this area in the 1950s, when experienced scientists studied Orthoptera there (Mařan 1954). *P. giornae* was not detected in any surveys conducted in the early 1990s. Despite thorough surveys, it was only found in 1998 in two specimens on a steep dry slope just above the Danube (Kočárek 1999), and it was not recorded elsewhere in the Burda Hills and surroundings during those investigations. A few years later, abundant populations were recorded in other localities of southern Slovakia (Krištín et al. 2007), and after a further ten years, *P. giornae* had become very abundant in the Burda Hills. Recently, up to one-tenth of the mapping squares at an elevation of up to 330 m have had abundant populations of *P. giornae* (> 100 adults/1000 m^2) (Krištín et al. 2020).

Hungary. It was first recorded in Hungary in 1912 (Harz 1975, Nagy et al. 2010), and by the mid-20th century, it was known to occur in many locations (Rácz 1998). Even in these long-occupied countries, population densities have demonstrably increased. By gathering new and unpublished data, the number of localities with *P. giornae* also increased in Hungary (Nagy et al. 2010). Taking the new data into account, the frequency category of *P. giornae*, as determined by Nagy and Rácz (2007), changed from low to frequent (Nagy and Rácz 2007).

In neighboring Romania, the species occurs in all bioregions (Iorgu et al. 2008) and was known from many localities in the mid-20th century (Knechtel and Popovici-Biznoseanu 1959); however, *P. giornae* was considered rather rare (Iorgu and Pisică 2006, Iorgu et al. 2008). By the 2010s, it had reached a frequency of 33% in surveyed localities in the Carpathians, with records up to 1,182 m a.s.l. (Krištín et al. 2013).

In the Pannonian parts of Slovenia and Croatia, *P. giornae* represents a long-established component of the regional fauna, occurring in thermophilous lowland and hilly habitats influenced by Pannonian and sub-Mediterranean conditions (Gomboc and Šegula 2014). In Croatia, stable populations are known from the Pannonian region and adjacent uplands (Szövényi and Puskás 2012, Skejo et al. 2014). The high number of recent records, especially from Croatia, may partly reflect increased observer activity and the growing availability of citizen-science data rather than genuine range expansion. Historical records from northern Croatia, particularly from the Bjelovar area, document the presence of *P. giornae* since at least the mid-20th century, indicating long-term persistence rather than recent colonization (Šerić Jelaska and Skejo 2014). Similarly, populations in Pannonian Serbia, for example in the Zasavica area, represent long-established occurrences within the southern part of the Pannonian Basin (Skejo and Stanković 2014).

These southern Pannonian populations most likely constitute source areas rather than recently colonized regions. Given their geographical position, these long-established southern Pannonian populations may have played an important role in the subsequent northward spread of *P. giornae* into Central Europe, a hypothesis that could be tested using population genetic approaches.

Factors affecting range shifts in Pezotettix giornae.—The expansion of *P. giornae* across Europe appears to be synchronized, forming a distinct front. Further to the north of this front, isolated outposts have clearly been documented, which subsequently expand. These outposts are undoubtedly the result of passive dispersal (Wöss et al. 2011, Wöss 2017). It is highly likely that other orthopteran species are also regularly transported with plants from the Mediterranean region—both as inadvertent introductions of adults and nymphs, and as laid egg pods (Hochkirch et al. 2023). Another possible mode of passive dispersal involves attachment to vehicles or transport within vehicle compartments and along railway tracks (most likely for *P. giornae* in eastern Austria, Wöss et al. 2011). This has been documented for the bush-cricket species *M. meridionale*, which is of Mediterranean origin and began spreading northward in the 1960s (Vlk et al. 2012). Orthopterans can attach directly to car hoods or sheltered parts of vehicles, enabled by their specialized arolia (Grobelny et al. 2019, Köhler et al. 2022).

(i) Transportation. Considering the long-term intensive country-wide Orthoptera monitoring (e.g., Marhoul et al. 2019), the field survey conducted for this study clearly indicates dispersal of *P. giornae* in Moravia via road traffic. At the rest area at Lanžhot, where grasshoppers were recorded in shrub vegetation, a large rest area still exists where trucks regularly stop. In contrast, the species has never been found at the nearby railway station, despite the fact that this route has the potential to serve as a dispersal pathway (Ranner and Riegler 2004, Wöss et al. 2011). While *P. giornae* is abundant on the side of the road coming from Bratislava, only a few individuals have been recorded in the opposite direction near the village of Lanžhot or at the site 15 km from the border. However, it has never been recorded at all at a site 10 km beyond the border on the opposite side of the highway. These differences in abundance suggest a recent introduction via vehicular traffic from Slovakia, followed by gradual natural dispersal.

(ii) Climate change. For this predominantly Mediterranean species, a rise in temperature was a prerequisite for its expansion. In Central Europe, annual temperatures have increased by more than 1 °C over the past 120 years, with further increases expected (Lapin and Melo 1999, IPCC 2018). However, in addition to more favorable climatic conditions, the species must also find suitable habitats to establish. While some species can locate such habitats, central European stenoecious and extremely xerothermic species generally cannot. For these species, a lack of suitable habitats often leads to regional extinction, particularly among those that are poorly mobile (Liana 1992, Machatz et al. 2005, Berg et al. 2005, Poniatowski and Fartmann 2010, Holuša 2012), but this situation may rapidly alter under ongoing climate change, and even such species may ultimately re-expand northwards into Central Europe from southern source populations.

(iii) Habitat requirements. *Pezotettix giornae* inhabits a variety of habitats, including open woodlands, shrublands, meadows, and others (Pisică et al. 2008, Wöss 2017). It primarily occurs in ruderal areas and sparse shrub vegetation as well as at the edges of forests and paths. Here, it is typically found in low shrubs, dense old grass, and leaf litter (Ranner and Riegler 2004, Zechner et al. 2005, Nagy and Rácz 2007, Wöss et al. 2011). Under anthropogenic conditions, it can be found in high densities in these types of habitats (Pisică et al. 2008). The same habitats are occupied in southern Moravia. This relatively wide ecological tolerance aligns with the observations of Ranner and Riegler (2004) in northern Burgenland, where *P. giornae* was found in sparse Black Locust (*Robinia pseudoacacia* L.) groves and in the Burda Hills. The combination of habitat flexibility and transport-mediated dispersal is reinforced by the presence of anthropogenic habitats alongside roads and railways. We therefore hypothesize that this flightless species may also spread along such corridors via transportation (Wöss 2017, Krištín et al. 2020).

Although *P. giornae* is primarily found in ruderal habitats such as roadside verges, rocky slopes, forest edges, and clearings, it also occurs in meadows with vegetation up to 30 cm high and ground cover exceeding 80%. Such habitats form a network of linear structures that are often found within agricultural landscapes. Therefore, despite being a brachypterous (micropterous) species, *P. giornae* spreads intensively, particularly along roads (possibly via transport), forest edges, and riverbanks (see also Tscharntke and Brandl 2004).

(iv) Abandonment. We believe that the spread of *P. giornae* is further supported by another recent trend: the abandonment of agricultural landscapes, the ruderalization of fields, shrublands, and hedgerows, and the cessation of grazing. Successional processes can be spontaneous, driven by humans, or related to changes in land use, particularly the decline of traditional management practices in non-forested areas, such as mowing and grazing. This ultimately leads to climax succession (Špulerová 2008). Spontaneous succession usually results in forest ecosystems, except in extremely dry or wet habitats. It is generally considered an ecologically suitable method of restoring disturbed sites, as target species tend to become dominant over time (Prach et al. 2013). Although steppe vegetation has persisted on rocky outcrops in the Burda Hills, most non-forested areas of the Ipeľská Upland—of which the Burda Hills are a part—originated through deforestation and grazing (David 2009). Today, in the absence of grazing, these areas are undergoing succession, and the newly emerging successional stages represent highly suitable habitats for *P. giornae*. Consequently, *P. giornae* may decline again as succession proceeds with closed-canopy forest, although it can persist locally in open forest structures (e.g., edges, clearings, glades, and sparse stands) where warm, grassy microhabitats remain available.

The widespread abandonment of agricultural land was common throughout the 20th century in the Carpathian region. This process began early on and had already become significant during the interwar period and the socialist era. However, the rate of farmland abandonment increased sharply after the collapse of socialism, reaching its peak between 1990 and 2000 (Munteanu et al. 2014). The Carpathian Basin ranks among the European regions with the highest rates of agricultural land abandonment between 1990 and 2006 (Hatna and Bakker 2011). Consequently, the abundance and number of *P. giornae* localities have increased, not only at the margins of its range but also within its core distribution area, corresponding to the species' expansion during the 1990s.

P. giornae is not the only species of Mediterranean Orthoptera that is spreading through similar mechanisms associated with passive dispersal followed by gradual occupation of suitable habitats. *Rhacocleis annulata* Fieber, 1853 has recently been recorded outside its native range in several Central European countries, with many occurrences linked to garden centers, nurseries, and other anthropogenic habitats, indicating repeated passive introductions via horticultural trade, comparable to the processes inferred for *P. giornae* (Staufer and Forsthuber 2021, Monnerat et al. 2020, Wolf 2024, Ćato and Zagorac 2021). Similarly, isolated records of *Anacridium aegyptium* (Linnaeus, 1764) north of its traditional range are often interpreted as transport-mediated introductions rather than natural range expansion (Gojznikar et al. 2018, Pavlović 2019). As with *P. giornae*, ongoing climate warming and increasingly mild winters likely facilitate the survival and potential establishment of such introduced individuals (Puskás et al. 2024). Together, these cases suggest that artificial dispersal combined with improved climatic suitability represents a common pathway enabling the northward spread of Mediterranean Orthoptera in Europe.

Conclusion

P. giornae demonstrates that, like long-winged and strong-flying forms, smaller brachypterous orthopteran species are also capable of dynamic dispersal. The primary factor driving this spread is likely climate warming, given that this species is a habitat-generalist and is not tightly associated with specific plant communities. Another significant factor is intensive transportation movements across the European continent, which facilitates the introduction of *P. giornae* via plant material or directly on vehicles. This results in the formation of isolated populations outside the native range, from which the species can gradually expand and shift the boundaries of its distribution. These findings are important for understanding species dispersal dynamics in a changing environment and could help with biodiversity monitoring and conservation efforts.

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Supplementary material 1

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Data type: csv

Explanation note: Abundance or population densities of *Pezotettix giornae* in the southeastern Czech Republic in the 2020s and Slovakia in the 1990s and 2010s, including survey period and area of study sites. Darwin Core complaint occurrence table of surveys in CZ and SK.

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